Planning future biomass to energy facilities on a gis offer/demand basis: a study for Tuscany, Italy

PLANNING FUTURE BIOMASS TO ENERGY FACILITIES ON A GIS OFFER/DEMAND BASIS: A STUDY FOR TUSCANY, ITALY

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ABSTRACT: In Tuscany, the use of biomass as energy source is not a new issue. Firewood is a common energy vector in rural areas where it is used since it is strongly competitive in price in comparison with locally available fossil fuels. Furthermore, in the most recent years an exponential growth of biomass heating district and cogeneration plants took place.
For these reasons, a proper planning of local investments in district heating and cogeneration plants is strictly necessary, supporting local authorities in planning investments in the biomass to energy chain, first of all by correctly evaluating the biomass supply actually available.
The Green Energy Model (GEM) has been developed in order to assess biomass availability. Both the ecologically sustainable production and economically sustainable production are available; the methodology also analyses the potential heat energy demand. Matching offer with demand allows pointing out the most suitable areas where to install new biomass energy district heating plants, thus.
At the same time, six biomass district heating plants have been monitored in Tuscany, starting at the beginning of the 2010 winter season and ending in spring 2012, thus including about two winter seasons, with particular attention devoted to monitor quality, characteristics and provenience of the wood chip fuel. Monitoring results is allowing the definition of new governance policies and actions by the local authorities.
Keywords: geographical information system (GIS), production, demand, monitoring.

1 INTRODUCTION

In Tuscany, the use of biomass as a renewable energy source is not a new issue. Firewood is already a common energy vector in rural areas, where it is used since it is strongly competitive in price in comparison with available fossil fuels (heating oil and LPG), and also because most of the mountain areas are still not reached by the natural gas distribution network.

Therefore, in Tuscany, firewood consumption is estimated around 1.2 million cubic meters each year, mostly concentrated in mountain areas where more than half a million people, presently representing about 13% of the total regional population, live. On the other hand, 1 million hectares of forest are still underutilised, a production surface that may allow a joint production of firewood and wood chips. In relation to the wide availability of forest land (wood index 0.45), in the most recent years an exponential growth of biomass heating district and cogeneration plants took place. Since 97% of regional wood production is presently represented by firewood, the development of heating networks in rural areas may represent a strong competitor towards the forest enterprise specialised in fire wood production. In addition, the strong development of biomass cogeneration plants is increasing demand for chips, not always locally available.

For all these reasons, a proper planning of local investments in district heating and cogeneration plants, able to take into account the actual availability of local biomass, the biomass of exogenous origin and the real presence of professional forestry enterprise, is strictly necessary. Particular attention should be devoted to support the local authorities in correctly planning investments in the biomass to energy chain, first of all by correctly evaluating the biomass supply actually available. CREAR, the Research Centre on Renewable and Alternative Energies of the University of Florence has been involved as Scientific Coordinator in the Project "BIOMASS" coordinated by the Province of Lucca, with the aim to provide a support to biomass to energy development planning.

The Green Energy Model (GEM: A GIS oriented model for the farm and the territory energy planning) has been developed in order to assess biomass availability. The methodology includes both biomass resources growth models and specifically developed economic models. The methodology gives a realistic evaluation of the available forestry resources, since taking into account forestry production costs allows the identification of the wood surfaces with a positive "stumpage" price. Two main data results are available: the "virtual" production, which is the ecologically sustainable production, and the "real" production, which is ecologically and economically sustainable. The real production is, thus, associated to an ecological sustainability and also has net positive revenue; it is evaluated taking into account the production costs (felling, machineries etc.) compared with the actual market price for woody biomass.

The methodology also analyses the potential heat energy demand, localising the areas where new plants could be installed, taking into account economics, territorial and competing markets (i.e. existence of a natural gas network). Matching offer with demand allows pointing out the most suitable areas where to install new biomass energy district heating plants, and cogeneration plants. In particular, the results of the ongoing monitoring of six biomass district heating plants installed in Tuscany in the last years have been taken into account. In fact, within the "BIOMASS" project activities, five biomass district heating plants are presently under monitoring in the Tuscany provinces of Pisa, Lucca and Massa Carrara. Monitoring started at the beginning of the 2010 winter season and ended in late spring 2012, thus including about two winter seasons. The main running parameters of the presently active plants have already been monitored, with the aim to provide the plant managers with a set of suggestions and instructions to improve the overall plant efficiency, to optimise the biomass to energy chain, and assess the economic sustainability for all actors involved in the energy supply chain.

Particular attention has been devoted to monitor quality, characteristics and provenience of the wood chip, organization of the wood chain and identification of

economic efficiency index for heating district plants.

In Tuscany, the area object of the study, district heating plants are mainly public and they provide energy to public buildings heating, as well as to private households. The problem it is how to estimate the economic efficiency of these two "production lines" (public and private). The study pointed out a set of economic indicator able to determine the economic feasibility for this specific configuration plant.

Monitoring results have allowed the definition of new governance policies and actions that will be defined by the local authorities (at province and regional level).

2 GEM (GREEN ENERGY MODEL)

In order to support local authorities in correctly planning investments in the biomass to heat sector, the woody biomass quantities available (offer) and the need of heat (demand) at local level has been assessed through GEM (Green Energy Model), a specifically developed GIS based methodology, that has been applied to the areas under investigation.

2.1 GIS data

Within the last ten years, a GIS related to the Tuscany territory and mainly devoted to the Land Use from the agro-forestry point of view has been implemented at the CREAR [1].

The land use layer, in particular, has been obtained merging and updating information starting from two main layers, the Tuscany Forestry Inventory (Inventario Forestale della Toscana - IFT) and the CORINE Land Cover (2004).

Besides the former land use layer, the following GIS layers are used for the biomass availability (offer) assessment:

- DTM;
- geology;
- climate;
- Landscape system (Sestini units).

The layers used for the heat demand assessment are the following:

- CTR (Carta Tecnica Regionale);
- road network;
- natural gas distribution network.

2.1 The Model

The biomass assessment model implements ecological, technical and economic aspects.

On the basis of land use, climate, geology, landscape etc. it calculates how much traditional assortment and residues are produced from each different forest typology.

GEM implements growth models that estimate the annual productivity of each forest type under the constraint of ecological sustainability.

Particular emphasis has been given to the quantification of the potential production of wood products for energy, such as firewood and wood chips, in relation to the local market prices, economic variables and technical organisation of production.

This type of evaluation alone, however, ignores the real opportunity to use the land, because it does not assess the economical sustainability of forest operations necessary to produce the biomass.

A supply model able to define the production areas in relation to economic parameters (wood prices, chips price, production and transport costs, etc.) has been developed and integrated into GEM, thus.

The heat demand is assessed on a geographical basis considering several factors, such as:

- heat demand density of buildings (private, public, industrial, greenhouses etc.) based on single building volumes;
- distance from natural gas distribution network;
- distance from roads;
- presence of public buildings (concentrated heat demand).

Areas with higher heat demand density are selected by the model for potential new district heating setup.

While the biomass availability assessment has been performed on the whole Tuscany territory, the heat demand assessment has been performed on the Province of Lucca (project target area) alone.

3 BIOMASS AVAILABILITY ASSESSMENT

Several different scenarios, based on different market hypothesis, have been simulated. The main results of two most interesting scenarios are presented in the following.

The first scenario (Scenario 1) considers the present traditional production in Tuscany: timber and firewood; results of the assessment will be compared to the actual data from statistics. The second simulated scenario (Scenario 2) makes the hypothesis to better the present traditional production (timber and firewood) associating to this the production of wood chips from residues.

Table I: ecologically sustainable firewood production potential on a Province basis in Tuscany as calculated by the GEM

Province	**Firewood (t/y)**
Arezzo	359 208
Firenze	348 328
Grosseto	358 880
Livorno	77 207
Lucca	127 587
Massa Carrara	107 544
Pisa	177 215
Pistoia	69 542
Prato	25 442
Siena	338 889
Tuscany	**1 989 844**

3.1 Scenario 1

The ecologically sustainable firewood and timber potential in the present scenario has been elaborated by the GEM. The results for firewood production potential are presented in Table I. Data on actual coppice firewood utilisation in Tuscany are available from ISTAT (Istituto nazionale di statistica - Italian National Statistics Institute). Statistics state [2] that present firewood utilisation is around 1127200 m3/y. If compared with the potential calculated by GEM, which is around 1990000 t/y (around 2840000 m3/y, thus), it can be pointed out that 40% of the ecologically sustainable potential is

presently used.

The potential figures are closer to actual if economics are considered. In fact, if economic parameters are considered, the potential coppice firewood production, considering the actual prices (at the consumer) range that is in between 100 and 130 €/t, decreases in the range (table II): 696000 - 900000t/y (994000 - 1286000 m3/y); the official statistics (1127200 m3/y) falls in the calculated range, thus according to the estimated value for Scenario 1 as calculated by the GEM.

Table II: firewood production potential on a Province basis in Tuscany as calculated by the GEM depending on the price to the consumer. Actual price ranges in italic (100~130€/t)

Province	**Firewood Price to the consumer (€/t)**			
	70	*100*	*130*	160
Arezzo	47 603	*144 183*	*180 927*	191 037
Firenze	46 197	*135 245*	*166 187*	174 537
Grosseto	41 337	*107 211*	*156 008*	177 103
Livorno	7 963	*30 750*	*36 996*	39 226
Lucca	11 936	*24 491*	*29 913*	32 596
Pisa	21 316	*51 929*	*65 841*	70 785
Prato	3 900	*8 652*	*10 851*	11 384
Pistoia	12 268	*22 766*	*28 919*	31 131
Massa	11 846	*28 946*	*33 993*	36 139
Siena	43 600	*141 827*	*190 725*	202 089
Tuscany	**247 966**	***695 999***	***900 360***	**966 027**

The curve representing biomass availability depending on the market price is represented also in Figure 1.

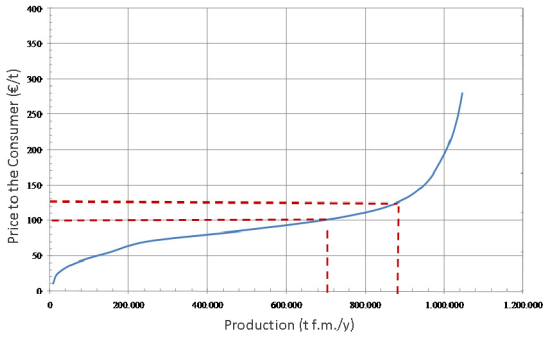

Figure 1: calculated firewood production potential depending on the price to the consumer.

3.1 Scenario 2

Scenario 2 represents the present traditional production (timber and firewood) with an associated production of wood chips from forestry residues. Due to the low accessibility of forests in Tuscany, mainly because of the lack of forestry roads and high slopes, in order to allow an economically efficient recovery of residues, it is necessary to make the hypothesis to change the present forest yard organisation to full tree recovery. As already stated, this is mainly necessary for chain economics.

Under the former hypothesis the resulting full tree recovery products are firewood, timber and wood chips from residues.

The assumptions on energy use routes foresee for firewood the destination to firewood market (where the price to the consumer is considered in the range 100~130 €/t) while wood chips address the small/medium size boilers market (where the price is in the range 69~83 €/t).

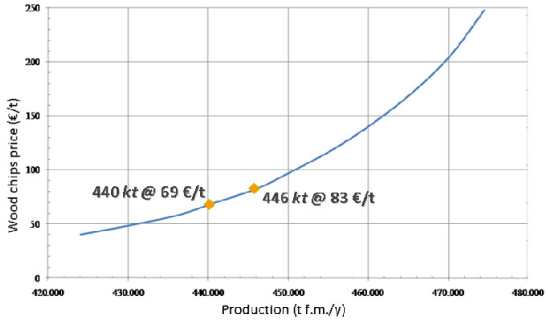

Figure 2: calculated wood chips production potential depending on the price to the consumer.

Wood chips production in the range of actual prices is presented in Figure 2.

The effects on the biomass availability of the combined production of firewood from coppice and wood chips from residues have been investigated.

The combined production of firewood and woodchips creates new revenue for the forest operator thus giving a higher value to the wood production. This increases the wood surface reaching a positive stumpage, thus increasing the potential (sustainable and economical) production.

The effect of the wood chips (from residues) price variation on economically sustainable firewood production has been calculated considering the two present price limits:

- minimum firewood price 100 €/t
- maximum firewood price 130 €/t

Table III: firewood production if combined with wood chips production, depending on the wood chips price to the consumer, if firewood price to the consumer is 100€/t

Tuscany	**Wood chips price (€/t)**			
	57	69	83	100
Firewood production @100€/t	940 862	957 915	971 364	984 330

If firewood production @ 100€/t market price is considered, in Scenario 1 it was around 696 kt/y; if income from combined wood chips production is taken into account it increases up to a minimum of 958 kt/y (+37%) (table III).

Table IV: firewood production if combined with wood chips production, depending on the wood chips price to the consumer, if firewood price to the consumer is 130€/t

Tuscany	**Wood chips price (€/t)**			
	57	69	83	100
Firewood production @130€/t	996 515	1003 716	1011 830	1019 155

If firewood production @ 130€/t market price is considered, in Scenario 1 it was around 900 kt/y; if

income from combined wood chips production is taken into account it increases up to a minimum of 1003 *kt/y* (+11%) (table IV).

4 HEAT DEMAND ASSESSMENT

The heat demand assessment has been performed on the Province of Lucca (project target area) alone.

The areas with the best vocation for the implementation of a biomass to heat plant (district heating) have been pointed out.

The heat demand of each single building has been computed based on the building volume (area and roof height are available from the CTR), the destination use (private house, industrial building, greenhouse, public building etc.) and the most common building age of the area under evaluation. This is a "maximum" heat demand, since the calculation performed does not take into account the real use of the building (i.e. primary or holiday house). The distance from the natural gas network has been taken into account. Areas easily reachable from the NG distribution have not been considered for the substitution. The positive effect of heat demand aggregation (and distribution in time) of the presence of public buildings has been also taken into account, also. The map showing the results of the simulation is presented in Figure 3.

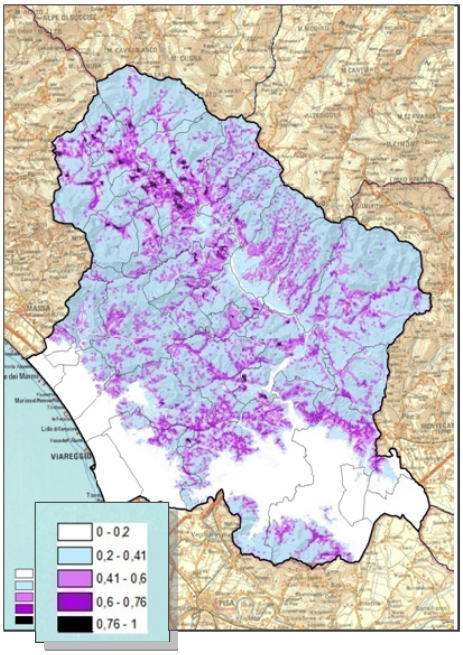

Figure 3: vocational areas for biomass based district heating implementation in the Province of Lucca.

The implemented GIS also allows the visualisation of each building main characteristics, including theoretical heat demand (figure 4). The next step foreseen for the GIS improvement is to include the available statistics on building utilisation (primary or holiday house) available from the official statistical data.

5 PLANT MONITORING

One of the main problems encountered during the plant monitoring it has been the low quality of the wood chips provided to the plants (in terms of Moisture Content) [3].

In fact, during the first phases of the monitoring (Winter 2010 and early spring 2011), in several cases the measured moisture content of wood chips provided to the plants has been found widely greater than the moisture content declared from the wood chips provider and that is, usually, specified into the biomass supplying contract (MC 30%). Wood chips samples with a measured Moisture Contents up to 56% have been reported. Most of the plant managers trusted the moisture content declared by the provider, so that no check or analysis has been performed on the biofuel before the monitoring started.

The bad quality of wood chips has been publicly put into evidence after the first months of monitoring (late spring 2011) in meetings with local authorities and plant managers.

After the dissemination action of first preliminary results, the providers paid more attention on wood chips quality. As a result, moisture content decreased to agreed values suddenly after results presentation.

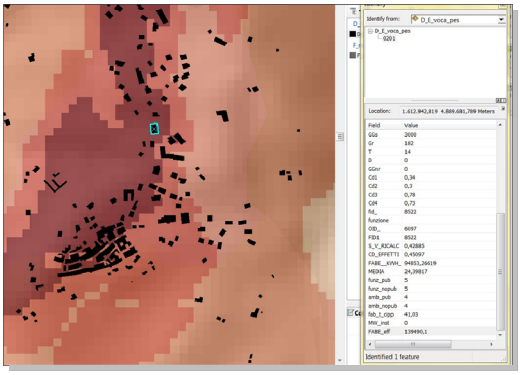

Figure 4: information window for each building

The effects of dissemination of the results on the provided biomass are evident from Figure 5.

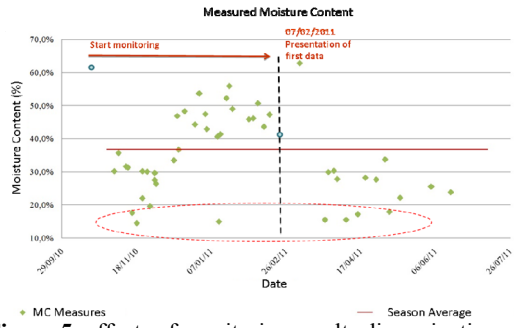

Figure 5: effects of monitoring results dissemination

6 CONCLUSIONS

Regarding the Sustainable (economically and ecologically) biomass production in Tuscany, this has been evaluated depending on biomass market price, while the theoretical heat demand has been evaluated only in the Province of Lucca; efforts will be devoted in the next future to the improvement of the data and in assessing the best "near to actual" heat demand.

Monitoring fostered the biomass providers to improve the biomass to energy chain in order to provide better quality fuel to the existing plants.

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8 ACKNOWLEDGEMENTS

The authors wishes to thank the European Commission for the support to the activity of the Project "BIOMASS energia che cresce" within the Marittimo Italia Francia framework.

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